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Andersen, Maj Munch

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Maj Munch Andersen
Technical University of Denmark
mmua@man.dtu.dk

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Maj Munch Andersen,

Department of Management, Danish Technical University, Lyngby,

mmua@man.dtu.dk, http://www.man.dtu.dk

Abstract

The last few years green innovation or 'eco-innovation' is increasingly recognized as a main driver and goal of economic development. This represents a marked shift from earlier when the environment generally was considered a burden to business. This paper seeks to contribute to a fundamental evolutionary economic theorizing on the dynamics of the "greening" of the economy, a theme which has been little analyzed so far. The paper suggests that the greening of the economic process should be seen as one of the most innovative changes in recent economic evolution entailing a major structural change of the economic system. The discussion aims more generally to contribute to the understanding of the dynamics of techno-economic paradigm shifts. It is argued that green economic evolution represents an interesting case of how selection properties are undergoing change over time, a neglected theme in evolutionary economics. The paper concludes that we may see the emerging 'green economy' as a specific historic era reflecting important changes in competitive conditions characterizing the modern knowledge economy. The paper contributes mainly to a micro-theoretical discussion forwarding a strong paradigmatic explanation of (green) economic evolution. At the micro level, the paper argues, and seeks to exemplify, that eco-innovation dynamics are characterized by both processes of creative destruction and creative accumulation. The paper proposes that it is possible to define a specific green heuristics leading to a fundamental 'green trajectory' at the very general R&D level. The impact and pervasiveness of eco-innovation is at this very basic level influencing on the entire economy. The techno-economic paradigm change should be seen as a function of partly changes in the underlying trajectory and partly changes in the selection properties.

Keywords: Eco-innovation, evolutionary economics, economic evolution, techno-economic paradigm change, technological trajectories

1. Introduction

A core theme in evolutionary economic theory is to analyze the rate and direction of technological change (Dosi, 1982, Nelsons and Winther, 1982). The overall question addressed in this paper is what makes the economy move in a more or less 'green'direction? What characterizes and shapes this direction and how continuous is it likely to be? This paper seeks to contribute to a fundamental evolutionary economic theorizing on the dynamics of the "greening" of the economy, a theme which has been little analyzed so far from this perspective.

The theme of the greening of the economy is more topical than ever. Climate change mitigation has over the last few years come to present one of the most important global policy goals shared across policy domains and regions. While this is surprising in itself the main novelty is that green innovation, or 'eco-innovation', increasingly is recognized as a main driver and goal of economic development. What is interesting is that only a few years ago the environmental agenda had a much more peripheral standing and the expectations as to the effects on the economy were moderate if not directly negative. Generally speaking, environmental issues were considered a burden to business and overall competitiveness by both business and policy makers (Kemp and Andersen, 2004). Accordingly, innovation policy and environmental policy used to be opposites '(Andersen, 2004, 2009). Green growth' has rapidly become a mainstream global policy target .There is a new global race to become leaders in what leading politicians term "the green industrial revolution" or the "New green deal" (Obama, 2009; Brown, 2009). Eco-innovation is even seen as a means to 'green recovery' in the current serious global financial crisis (Milliband, 2007; Barroso, 2007; Andersen, 2009; Andersen and Foxon, 2009, OECD 2009). The dramatic rise of the climate agenda has hence had a significant effect on the policy area but also, and for this paper more important, more generally on the economic development.

The novel concept of 'eco-innovation' is increasingly connected to green growth by policy makers, but is currently very fuzzy. It is being used by many disciplines and in need of theoretical and empirical clarification (OECD, 2009). This paper proposes that the concept of eco-innovation, as other innovations, may best be understood and defined from an evolutionary economic perspective and that core Schumpeterian themes may be helpful in understanding the dynamics of the "greening" of the economy.

The paper suggests that the greening of the economic process should be seen as one of the most innovative changes in recent economic evolution entailing a major structural change of the economic system. The discussion aims more generally to contribute to the understanding of the dynamics of techno-economic paradigm shifts.

It is argued that green economic evolution represents an interesting case of how selection properties are undergoing change over time, a neglected theme in evolutionary economics. The paper concludes that we may see the emerging 'green economy' as a specific historic era reflecting important changes in competitive conditions characterizing the modern knowledge economy. The paper contributes mainly to a micro-theoretical discussion forwarding a strong paradigmatic explanation of (green) economic evolution. At the micro level, the paper argues, and seeks to exemplify, that eco-innovation dynamics are characterized by both processes of creative destruction and creative accumulation. The paper proposes that it is possible to define a specific 'green trajectory' at the very general R&D level. The impact and pervasiveness of eco-innovation is at this very basic level influencing on the entire economy. The (green) techno-economic paradigm change should be seen as a function of in part changes in the underlying trajectory and in part changes in the selection properties.

Currently, theoretical and empirical insights into the greening of the economy are poor. Mainstream neoclassical economic research, which has dominated environmental research and policy-making, has failed to realize that markets are going "green". The assumption of rational agents preoccupied with short run allocative questions exclude such considerations. But, and more surprising, also evolutionary economics has largely neglected to address green economic evolution. Evolutionary economic research into the greening of industry and the economy is limited and mostly fairly recent. See though e.g. (Fussler and James, 1996; Andersen, 1999, 2002, 2006, 2007, 2008a 2008, 2009a, 2009b; Andersen and Foxon, 2009; Andersen et al. 2010; Fukasako 1999, WBCSD 2000, Rennings, 2000, 2003, Hübner et al 2000; Markusson, 2001, OECD 2005,2009; Kemp 2000; Kemp and Andersen 2004; Kemp and Pearson, 2007; Foxon, 2005, 2007; van den Bergh et al., 2006, 2007; Reid and Miedzinski, 2008; Carrillo-Hermosilla et al. 2009). Much of this research has hitherto had a strong focus on policy issues and their innovation effects, while little attention has been paid to analyzing the eco-innovation dynamics per sé. We know hence currently very little both theoretically and empirically on the dynamics of the greening of industry and the economy. An indicator of this is the very poor data sources and indicators on eco-innovation (Andersen,

2007; Kemp and Pearson, 2007; OECD, 2009). It is e.g. only within the last 1-2 years that environmental issues or "sustainability issues" have become central topics of leading innovation economic conferences[1]. This reflects, the paper claims, some shortcomings in evolutionary economics in interpreting the innovation process and economic evolution. Important features of the innovation process are neglected, noticeably those related to changes in selection properties and more specifically changes in the treatment of negative externalities of production (such as environmental degradation, as we shall return to later). The latter negligence may be due to the implicit assumption in evolutionary economics that innovation is good for societal development. In the quest of evolutionary economics to become recognized as real economic disciplin, the focus has quite narrowly centered around linking up selection to productivity, profitability and growth. The goal of innovation policy is a higher innovative capacity which is seen as the core means to economic growth. Only more lately have more societal goals, and none the least eco-innovation goals come to form part of this (Andersen, 2004, 2009). The attention to societal effects of innovation are generally limited.

While Schumpeter argued that innovation is a core driver of economic and social change (Schumpeter, 1937), one may similarly argue that societal change is a major driver of innovation. The greening of the economy with its high element of policy, offers an interesting opportunity to study the long-run co-evolutionary change in innovation and economic and social change. The well-established innovation systems framework seek to take on a broader more systemic perspective on innovation (see e.g. Freeman, 1987, 1995; Lundvall, 1992 (ed.), 2007; Nelson, 1993. The recognition of the importance of well-functioning institutional structures for a high innovative performance and economic development within this frame makes it the more remarkably that the externality discussion generally, and not the least environmental degradation, as mentioned has received little attention until now within this line of thinking (see though e.g. Hübner et al 2000, Kemp and Andersen, 2004, Foxon et al., 2005b, Foxon and Kemp, 2007; Andersen 2006, Andersen 2008a, 2009, Andersen and Foxon 2009 for some mainly policy oriented discussions from this perspective). A neglected theme in innovation systems analysis is how innovation systems evolve to handle negative externalities in novel ways and how this effects the overall performance of the innovation system. Today, most modern economies are quite far in having created the policy frame and infrastructure to handle environmental degradation and are struggling to find more efficient ways to

[1] Compare the Dime conference specializing on sustainable innovation in Bourdeaux 2008, eco-innovation (or similar terms) becoming a main theme at the DRUID conference for the first time in 2009 and the Schumpeter Conference in 2010. Sustainable innovation has been a theme at many environmental conferences for a number of years but it has not been addressed systematically from an evolutionary economic perspective.

support eco-innovation. Eco-innovation policy represents a very immature policy area but it is gaining a surprisingly rapid momentum these last 1-3 years brought forward by the climate mitigation wave, none the least at the level of international institutions such as EU, OECD and UN (EUROPEAN COMMISSION 2003, Kemp and Andersen, 2004; COM 2006; UNESCAP, 2007; EUROPEAN COMMISSION 2009; OECD 2009).

Overall, there is a serious lack of theoretical economic insights into the dynamics of the greening of industry and the economy. The current paper combines basic evolutionary economic insights adding insights more specifically from an evolutionary capabilities perspective (Teece, 1986; Langlosi, 1992, 2003,2004) and the innovation systems theory perspective.

Analytically, the frame may highlight how new eco-innovations co-evolves with (demanding) changes in the economic organization on the market and institution formation within and surrounding the market as the market goes greener (see also Andersen, 2009, 2010). The evolutionary economic perspective, then, opens up for the possibility that environmental issues can be internalised into the economic process, i.e. a greening of markets, though this entails a major transformation process of the economic process. Environmental problems are not a market failure, but rather an integrated part of the changing imperfections of the market (Andersen, 1999, 2002). Not being able to deal adequately with environmental problems is due to system failures in given national and regional innovation systems (Andersen, 2006; Foxon, 2008, Andersen and Foxon, 2009).

2. Eco-innovation and techno-economic paradigm change

The greening of markets, it is suggested, should be seen as a specific historic phase and part of a larger techno-economic paradigm change towards a "green learning economy" (Andersen, 2010). Many environmental searchers, some of these evolutionary economists, have pointed to the rise of the greening of industry as part of an overall techno-economic paradigm change, basically arguing that the greening process entails, or should entail, radical and systemic changes in production and consumption patterns (e.g. Summerer 1989; Kemp and Soete 1990; Kemp, 1994; 1996; Gladwin 1993). Lately there is also much reference in the climate debate of the shift from a high- to a low-carbon economy as a paradigm change (Unruh, 2000, 2002). There has, however, been little empirical analysis of whether there are actually signs of such an emerging paradigm change and little theoretical discussion about the nature and dynamics of such a paradigm shift (see though Freeman 1992; Andersen, 1999, 2002, 2008b, Andersen, 2009a, 2009b; Andersen and Foxon, 2009).

In Neo-schumpeterian theory and studies of innovation cycles, the paradigm discussion is used somewhat differently at a very macroscopic level. These researchers argue that there are some changes in technology that have so pervasive impacts on the economy that they will entail a techno-economic paradigm change (Dosi, 1982; Freeman and Perez, 1988; Perez, 2000, 2002). They emphasize the long wave relationship between economic and technological development arguing that such fundamental technological changes bring discontinuity in economic development but also act as important engines of economic growth (Freeman, 1982, Freeman and Soete, 1997, Freeman and Louca, 2004).

It is her argued that green economic evolution has led to a green wave of such a nature and scope that it has come to act as such an engine of economic transformation and growth. The greening of the economy is, however not about systemic technological change in a classical sense. As it will be argued later, eco-innovation is not á technology, but more about some (green) features which come to act as a selective property, impacting on all types of innovations. [The green economic evolution is, it will be argued, is about the degree to which environmental issues are becoming integrated into the economic process. Fundamentally this means that environmental parameters increasingly come to act as a selective device on the market.] It goes beyond this paper to discuss theories of techno-economic paradigm change in detail but.

This paper argues further, that the green techno-economic paradigm change is more than a technical substitution process, from none-green to green technologies or carbon based to low-carbon based technologies, but should more be interpreted as a process of creative destruction and creative accumulation at the very fundamental search, or R&D, level as we shall expand on. The green economic evolution should, it is suggested, be seen as the combined effect of the rise of environmental parameters as a selective device on the market and the accumulation of green trajectory.

2. Selection, innovation and eco-innovation

This section offers shortly some main arguments for a definition of eco-innovation from an evolutionary economic perspective. Fundamentally “eco-technologies”, now superseded by the concept of “eco-innovations”, are technologies or services which remedy environmental problems. There have been many different concepts in use over time to a large degree reflecting changes in environmental policy focus. With a still more preventive and integrated policy approach to environmental issues the

focus has changed from environmental technologies/End-of Pipe to cleaner production processes, cleaner products to the broader eco-innovation or, also widely used, clean-tech concept. Lately, low-carbon or climate technologies are added to the list of common concepts. Fundamentally, understanding eco-innovation entails understanding the changing relationship between society and nature over time and the attempts to develop novel solutions to deal with man-made environmental degradation. The paper will not go into a very detailed discussion of specific taxonomies of eco-innovation categories (see Andersen, 2006). For the point of the more fundamental discussion on eco-innovation dynamics and the greening of markets in this paper, we will stick to two main eco-innovation categories:

A. Pollution- and resource handling technologies and services.
B. All technologies, products and services, which are more environmentally benign than their relevant alternatives

These two main categories are well consolidated and in accordance with the EU definition of environmental technologies (EU Com, 2004).

From these two eco-innovation categories it is apparent that eco-innovation is difficult to define and address, both because of the complexity but even more the relativity of the subject. This goes particularly for the category B eco-innovations which are a lot more complex and fluid. Greening is a moving target; innovations which are considered green today may be outrun by greener alternatives at some point (Andersen and Kemp 2004, Andersen, 2006, 2008b; Kemp and Pearson, 2007).

Existing statistics mainly cover the category A eco-innovations (pollution- and resource handling technologies and services), while category B, the innovations which are greener than the alternatives, are more or less left out.

Issues of the role of negative externalities, including environmental degradation, for economic evolution have only been dealt with very limited from an evolutionary economic perspective. The externality problems, including environmental externalities, are treated as dynamic (Kemp and Soete,1992, Rennings 2000). The phenomena to which the “externality” tag is applied are not given but are related to particular historical and institutional contexts rather than definitive once-and-for-all categorizations (Nelson and Winter 1982). However, this discussion does not discuss the dynamcios intouch on the possibility that selection properties might change and hence internalize the externalities.

The novel eco-innovation concept is as stated quite fuzzy. Sharp and operational definitions are lacking and statistical data are poor (see Kemp and Arundel, 1998, Kuhndt et al., 2002a, 2002b, Arundel, Kemp and Parto 2004, Horbach (ed.) 2005, Andersen, 2006, Kemp and Pearson, 2007,

OECD, 2009b. There is raising political interest in the in developing better classifications and indicators on eco-innovation none the least at EU and OECD levels (see Andersen, 2007; OECD 2009a, 2009b. While eco-innovation hitherto has been defined in technical terms, also by evolutionary economists (Kemp and Pearson, 2007) focusing on which kind of environmental impacts the technologies remedy, it is here suggested to define eco-innovation in economic terms. *Eco-innovations are innovations which are able to attract green rents on the market* (see also Andersen, 1999, 2002, 2006, 2008a, 2008b, 2010). They are innovations which (appear to) reduce net environmental impacts while creating value on the market. Following this definition the eco-innovation concept is inherently linked to green competitiveness and green economic evolution. It is not decisive how green an innovation is but to what degree the environmental parameter has become a selection parameter on the market. Eco-innovation then is a measure of *the degree to which environmental issues are becoming integrated into the economic process.* Following this definition the concept intersects environmental degradation with innovation and economic performance. The eco-innovation concept signals that the environment is becoming significant for the economic process.

The eco-innovations may, as other innovations, be technical, organizational or marketing innovations as long as they improve the "green competitiveness" of a company (Kemp and Andersen 2004, Andersen, 2006, 2008b). [2] There are basically two ways a firm may attract green rents on the market: Either by acquiring a premium price for its green reputation or product, or to reduce production costs by achieving greater resource efficiency or reducing the costs of costly emissions. For the firm the greening process appears as turbulent changes in the selection environment, entailing new legitimacy needs and/or requirements for innovations. Different empirical studies have shown that incentives for engaging in eco-innovation vary widely for different types of firms and sectors (Malaman, 1996, Ulhøi, 2000; Horbach (ed.) 2005, Kemp and Pearson, 2007). The linked nature of the innovation process means that all firms play a role for the eco-innovation process, including none the least service firms, though their direct environmental impact may be small. We need, however, more empirical studies and theoretical analysis for a wider understanding of the patterns in firm eco-innovative behavior. For this type of in-depth analysis of eco-innovation dynamics on the market we need more detailed taxonomies of eco-innovations. This exercise goes beyond this paper, but for early thoughts on a taxonomy of eco-innovations see (Andersen, 2008b).

[2] The concept is related to the wider "sustainable consumption and production" concept (SCP), though the two concept areas have been little linked so far (see though Andersen, 2008, Tucker et al. 2008).

3. Defining a green trajectory

The techno-economic paradigm discussion is especially important because it points to the neglected cognitive roots underlying economic evolution. Evolutionary economic research into technological paradigms and trajectories emphasize how technology development, similar to scientific work, follows certain heuristics (Nelson and Winther 1982, Dosi, 1982). A research organisation's or firm's knowledge base is characterized by heuristics, which are theory-laden and upholding inner consistency (Dosi, 1982). Reigning techno-economic paradigms embodies strong prescriptions on the directions of technological change to pursue *(positive heuristics)* and those to neglect *(negative heuristics)*. A techno-economic paradigm entails a notion of "technological progress" which guides the direction of companies and knowledge institutions search processes (Dosi 1982).

The evolving green techno-economic paradigm change we may interpret as the rise of an increasingly accepted notion of *green (technological/innovation) progress* which influences on the direction of search processes of firms and knowledge institutions (Andersen, 1999, 2002). Furthermore, the greening process entails specific green heuristics at the fundamental R&D level (see Andersen, 1999, 2002). The core assumptions in the green heuristics may be coined by the concept of 'eco-efficiency' Eco-efficiency relates service or economic performance to the degree of environmental impact; i.e. an activity is eco-efficient the more service is achieved with minimum resource use and overall environmental impact [3](Daly, 1984; WBCSD, 2000.). We may at the micro level and meso level (industries) perceive of a competition between a "wasteful" theory (negative heuristics) where there is little attention to the environmental impact in normal problem solving activities and an eco-efficiency theory (positive heuristics) where there is strong attention to an efficient use of resources in normal problem solving activities. The notion of eco-efficiency is theory-laden and upholds inner consistency and may guide search processes in quite fundamental if not precise ways. What has changed with the rise of greening as a corporate issue is that eco-efficiency has changed from being the negative heuristic, damaging to competitiveness, to becoming the positive heuristics, improving competitiveness. The argument of importance here is, that with the emerging techno-economic paradigm change, a green or eco-efficient trajectory evolves at the aggregate level and is increasingly 'in the air', or rather

[3] See (WBCSD 2000) for a full and quite precise definition of the eco-efficiency concept.

The concept of resource efficiency is nearly similar to the concept of eco-efficiency but with an emphasis on the source side (extraction of resources), whereas the eco-efficiency concept includes both the source and the sink (emissions) side. They are, however, often used as substitutes. The term resource efficiency has the advantage that it is immediately meaningful which is not the case for the eco-efficiency term.

embedded in the underlying knowledge base of an increasing number of industries and scientific communities (see Andersen, 1999). It is, in other words, possible to contemplate a notion of 'green problem solving', which despite the complexity of the eco-innovations, shares some quite fundamental principles

As stated the incentives and conditions for engaging in eco-innovations differ widely between different types of firms and sectors (Malaman, 1996; Andersen, 1999, 2006). In fact it has been argued that the process of the greening of industry is unusually uneven (Andersen, 1999). Heterogeneous firms have different abilities to tap into the emerging green capabilities and exploit the new green profit opportunities, a factor which is very little analyzed so far. However, this discussion which influences in important ways on the green economic evolution, goes beyond this paper..

The current discussion emphasis that the green paradigm change is more than a technical substitution process, from none- green to green technologies or carbon based to low-carbon technologies, but a more fundamental learning process, involving the creative accumulation of new heuristics and capabilities and the creative destruction of old insights, practices and capabilities.

4. Creative destruction and creative accumulation in green economic evolution

This section seeks shortly to discuss and illustrate how processes of creative destruction and creative accumulation result in green economic evolution. It is suggested to see the greening of the economy as a specific historical phase in the global economy, though with considerable regional and sectoral differences. The current discussion does not go into details with the phases and trends of this process. Rather focus is on discussing the nature of these processes. Short examples are given from two different periods and two different value chains. Respectively the paper chain in the mid 1990s and the window chain in the end 'zeroes'. However, as a core argument is that history matters and that green economic evolution is influenced strongly by path dependency, a short general historic account is necessary. The account takes the development in the relatively environmentally advanced developed economies as the focus of analysis. Green economic evolution evolved in the 1950s with the rise of environmental policies seeking to regulate industrial pollution. This (reactive) phase has prevailed for over 30-50 years and has cemented the environment as a burden to business. From the mid 1980s we saw the first more preventive or product oriented environmental policies and the first environmental strategizing among pioneering companies. In the mid zeroes, starting only 2-3 years ago and still accelerating we see an explosive growth in environmental strategizing and eco-innovative activities

widespread in the economy (Andersen, 2010). Over this period the conditions for eco-innovation has vared considerable. As a consequence of this history, the economy is currently highly locked-in to carbon based and wasteful technologies and the shift to a low carbon, resource-efficient economy is therefore likely to be costly and entail considerable creative destruction. Some industries and economies may suffer substantially in the process and offer resistance to the greening of the economy.

Experiences from the Danish paper chain in the 1990s

The paper industry were among the first sectors to develop proactive eco-innovation strategies[4]. This was partly due to the fact that the industry belonged to the more polluting, with a very visible point-source pollution (rivers turning white with waste water from the paper mills, fish dying ect.), and huge amounts of solid paper waste. At the same time the paper industry was also among the traditional recycling industries. Old cloth and later waste paper had long been an important raw material in the paper industry. Recycled paper and board became one of the first examples of green consumer products, and policies to enhance paper recycling were numerous mainly consisting of collection schemes and eco-labels. Consumers took a first active green stance as they volunteerly participated in paper waste separation (late bottles followed and much later plastic). The Danish paper industry was and is very small, consisting of only a few companies. The industry was facing difficult competitive conditions surrounded by some of the world's largest paper industries in Sweden, Finland, Norway and Germany. The mills in these countries were generally newer and bigger, the latter factor essential for the productivity of these firms. As paper production is highly capital intensive, the strategy of the Danish producers were to upgrade the existing machinery. One of the companies, Grenaa Papir, produced nearly 100 pct recycled corrugated board. The use of waste paper was introduced entirely for economic reasons, as it was more economic that wood in a Danish setting and quite common within most board segments (in opposition to paper segments). However, as recycled paper began to become a selection property the firm started to market their products as green products towards their business customers but not very forcefully. It became an element among the other quality criteria of the product. The redefinition of their products into a green product, however was soon associated with the rise of green search rules. Having made the first material input-output model, the head of production realized how resource inefficient their production had been hitherto, and extensive measures were made to make the production method more resource efficient. The mill achieved major productive gais through these measures. The mill, known to be very innovative, were among the first to obtain a 100 pct. closed water circulation system, technically very difficult together with a 100 pct waste paper

[4] The following account builds on the in-depth analysis made in (Andersen, 1999).

based system. The firm collaborated closely with its chemical suppliers on these innovations, the chemical companies possessing much of the R&D capabilities in the chain. As the chemical industry were among the most scolded industries for being 'ungreen' with their often highly toxic products, these companies were eager to develop a more green profile and early to search for green profit opportunities such as For some years the firm competed successfully, but had to close down eventually, as its paper machine plant was too small and inefficient compared to the foreign competitors. A high green profile is no guarantee for competitiveness.

One of the other Danish companies, the small Dalum Papirfabrik, developed a deliberate strategy to exploit the new green profit opportunities, and shifted their production to 100 pct. recycled high quality office paper, a rare niche product at that time and technically difficult. They started to market their product as a green product taking a small premium price, a process that was difficult and required demanding interfirm coordination, as the product to some degree initially was incompatible with complementary products (such a ink, glue, copy machines and printers) and wholesalers, retailers and end users were skeptical as to the product quality. The company was quickly bought up by the large Stora multinational paper corporation who were interested in the green niche as part of their portfolio. Although the company initially focused on the recycling part of the product it soon started to engage in wider eco-innovative activities, seeking to make the production process more green and resource efficient. Turning green entailed obligations, e.g. to achieve eco-labels in order to undertake green marketing. It became a necessary standard to have a certified environmental management scheme. These measures influenced on the search rules of the company which turned increasingly green, i.e. green learning took place. The company still survives with this green niche product as the only surviving paper mill in Denmark.

The third and last Danish paper mill is Brødrene Hartmann, which was and is quite a big producer of moulded board for packaging, mainly used in egg trays and vegetable trays. They also relied traditionally on 100 pct waste paper, as their competitors did too. With the greening of the market they identified a new profit opportunity in developing customarized packaging products for industrial customers replacing PVC based packaging. PVC was at the time receiving strong critique and much policy attention for its contribution to dioxin pollution through waste incineration. PVC was, opposite to recycled paper, one of the early symbols of a 'none-green' product, which also consumers learned to avoid. Brødrene Hartmann competed very successfully in this segment, and the PVC industry faced difficult times and eventually closed down or shifted their production. Also within Brødrene Hartmann we see the strengthening of green search rules accompanied by a range of eco-innovative activities. The firm early became one of the main green pioneers among Danish companies, and developed

some of the most advanced environmental management systems and life cycle based supply chain management systems.

Common for this industry and period is that the market increasingly works as a green selection device. New products as well as a redefinition of existing products are aimed at the green market. The green dynamic transaction costs are high and the firms have to engage in building market mediation institutions in order to market themselves green as market supporting institutions are not yet in place. But these firms were willing to undertake these costs which seemed to pay of. It is also noticeable that for all the case firms, substantial green learning has taken place which continues, regardless of the original motives of their green strategizing. A green identity influences both on the branding and the search processes.

Experiences from the Danish window chain in the end zeroes [5]

The traditional construction industry is known to be conservative, low R&D and little innovative, knowledge accumulation being hampered by the project like nature of much of the innovation. The vertical specialization of the chain is characterized by R&D in the window chain is to a large degree contained with the large multinational glass companies, many fairly small suppliers and a range of small project oriented construction companies. The construction sector accounts for approximately 40 pct of over all energy consumption. With the rising attention to energy efficiency as a policy goal following the topical climate agenda, energy efficiency has become a key driver of innovation in the sector. There are widespread expectations among the companies that stricter policies for energy efficiency will be introduced and that energy efficiency is a key concern that will stay. In the window industry the role of windows have changed from being part of the energy problem in the eighties and 1990s to becoming part of the solution in the zeroes. Much product innovation into low energy and energy control window has taking place meaning that the best of the windows now contribute to zero emission building or even plus energy buildings. Much of this eco-innovation has been undertaking by the large glass companies, to some degree as a spillover from the more innovative car industry, the second biggest customer of flat glass. The most energy efficient windows are now more energy efficient than well insulated walls.

The opposite condition was the case in the 1980s. As part of the extensive policy measures to improve the energy efficiency of buildings the Danish authorities introduced limitations in the amount of windows that were allowed in new buildings. At that time the window producers were considered a none-green industry and developed quite defensive environmental strategies. While the glass had be-

[5] The current section is based on in-depth studies in (Andersen et.al, 2010).

come quite green the window frame has not, and policymakers and users were late in realizing that the window frames functioned as a thermal bridge. Design and maintenance were and still is an important product criteria and elegant wood-alu windows became popular despite in the 1990s and zeroes despite the fact that they are little energy efficient.

Lately, with the hot climate agenda we see a marked change in corporate strategizing. All actors in the Danish window chain are on intensive search for new green profit opportunities. The Danish window industry is dominated by one large Group, the VKR Group which has quite a high level of R&D, and else consists of many relatively small producers. Among the window producers one of the smaller firms, Protec, recently engaged in a radical product innovation shifting from alu-wood production into window frames made from composite materials, a much more energy efficient material. The innovation has been quite difficult demanding a range of complementary innovations, in e.g. handles, closing systems ect. So far the company competes successfully within this niche market. Also the firm Dovista, belonging to the VKR Group, has succeedingly engaged in the development of composite window frames, also aimed at the market for energy efficient windows. So far they are still under development, only being applied in green demo houses. The green demo houses, build by many municipalities, are seen as important sources of experimental product innovation where prices matter less. The production of wood and alu-wood frames continues to be the main standard in the VKR Group which needs to be able to supply large quantities in a verified quality. But the VKR Group is also recently engaged in quite radical eco-innovations in wood conservation. In 2006 they bought up the small upstart company Superwood, which sought to develop a new environmentally friendly method for wood preservation based on nanotechnology (the 'supercritical technology'). The superwood is alredy commercially available for consumer use. The VKR Group is still testing the wood in their green demo houses aon is enged in a further development of the product to serve the specific needs of wind production. We see an interesting strategic change among the VKR Group as the two main Danish window producers, the Dovista and Velux companies, are shifting from focusing on developing windows to acting as developers of green buildings. They are increasingly engages in systemic eco-innovation at the building level, integrating windows with advanced electronic systems and engaged in the design of houses for optimal utilization of daylight and natural ventilation. They function as the main actors in several green demo house projects. In this way they seem to be threatening the position of existing construction companies, overtaking a new role as system integrators on the green building market. The rest of the window producers, there are around 300 small Danish companies, continue to rely on wood and wood-alu window frames for the time being and may phase a difficult competitive environment in the future. The degree to which the novel green strategizing among the window com-

panies are leading to wider green search rules more widely in the industry remain to be seen. Within the VKR Group there is already well-developed environmental management systems and lifecycles assessment based search rules environmental concerns are well-integrated.

Overall, we see similar tendencies as in the paper case with growing green selection properties and the rise of green search rules and capabilities, but illustrating a somewhat delayed development in the window chain as compared to the paper chain in the green economic evolution. The original conditions for eco-innovation were less favorable in the window chain than in the paper chain, but this is changing dramatically in the last few years. The rapid recent greening of the window chain extending into the wider construction sector, illustrates the more consolidated stage of the green market. Market supporting institutions are largely in place or can quickly be established, also there are increasingly rising shared green expectations. Interdependent firms are generally moving in the same green direction though not necessarily at the same pace. Accordingly, the dynamics transaction costs are drastically reduced compared to the situation in the 1980s and 1990s when the green market was in an early and slow stage of development. Green capabilities are now fairly easy to tap into and environmental practices are well-established. As the market is growing greener, green competitiveness becomes increasingly important and influences on the selection of products, but very much, and for many companies and sectors more important for their green competitiveness, on the selection of employees, suppliers and customers, learning partners, financial and insurance institutes etc.

The cases, however, also illustrate that there is still a long way to go before the new green profit opportunities are more widely utilized and companies and technologies more generally are greening.

The cases show quite dramatic changes in the economic evolution the last 20 years, which is the period of the emergence of the green market. The two cases together illustrate clearly green economic evolution entailing qualitative changes in the economic system. We see how environmental issues come to act as a new selection property and companies move in to utilize the new green profit opportunities. Increasingly the market acts as a still more effective green selection device. As the green market grows the market supporting institutions become established. At the same time at the fundamental R&D level we see the emergence of green search rules and green capabilities which become increasingly widespread, feeding into an growing green underlying knowledge base. As there are sunk costs to eco-innovation it has become considerable easier to engage in eco-innovations, but the economic returns may also be lesser as many more actors are seeking to attract green rents.

5. Conclusions

This paper has sought to contribute to a fundamental evolutionary economic theorizing on the dynamics of the "greening" of the economy, a theme which has been little analyzed so far. The paper has argued theoretically, and sought to illustrate empirically that we the last twenty years have witnessed a significant green economic evolution. The paper contributes mainly to a micro-theoretical discussion of this trend forwarding a strong paradigmatic explanation of (green) economic evolution.

Using a mixture of core evolutionary economic thinking with specific insights from an evolutionary capabilities perspective the analysis feeds into discussions on the dynamics of techno-economic paradigm shifts. It has been suggested that the (green) techno-economic paradigm change should be seen as a function of partly changes in the underlying emerging trajectory and partly changes in the emerging selection properties. The paper has proposed that it is possible to define a specific 'green trajectory' at the very fundamental R&D level. Principles of eco-efficiency underlie the rise of green search rules and a growing green knowledge base. The impact and pervasiveness of eco-innovation is at this very basic level contributing significantly to processes of green creative accumulation widespread in the economy.

The paper argues that eco-innovation dynamics are characterized by both processes of creative destruction and creative accumulation. As the green market grows new green entrepreneurs enter, incumbents strengthen or shift their strategies towards the green profit opportunities and less-green actors are weeded out as the market increasingly functions as a green selection device. The cases have also illustrated how both companies and sectors may change their green reputation over time; sometimes as a consequence of the agency of the firm as they develop proactive eco-innovation strategies, at other times because of innovation leading to intentional or unintentional changes in the relative green performance of competing products, and sometimes due to changes in the selection environment, which redefines what is considered green and what is not. As the green market becomes more established, none-green sectors and entire technologies are being threatened by competing new greener technological trajectories.

We see in the cases adaptation to the new green profit opportunities and hence creative accumulation more than creative destruction. This may be due to the extent and nature of the green economic evolution. The green market is quite demanding with high information needs, requiring well-developed mediating institutions to succeed. Once established these act as self –reinforcing mechanisms sinking the transaction costs. Also, eco-innovations are intrinsically good and easily obtain a no-

tion of progress and positive heuristics. This means that firms generally are eager to pursue green profit opportunities when available. The creative accumulation happens primarily as a consequence of the widespread green learning associated with the green economic evolution. A green trajectory, understood as a new pattern of green/eco-efficient problem solving activity is evolving and becoming increasingly consolidated across industries.

While there is still a way to go before eco-innovation has become " the easy and natural innovation", technology in the two cases, the paper chain and the window chain, seems more generally to be moving in a green direction (Andersen, 2007, 2009a, 2009b, 2010). We need however, more studies into the sectoral specificities and chain dynamics related to eco-innovation , as we may expect considerable descrepancies in eco-innovative behavior.

The most recent dramatic growth in green economic evolution may, it seems, to some degree have reduced the lock-in into non green practices, capabilities and strategies which has restricted eco-innovation the last 50 years. The analysis points to sinking costs to eco-innovation more generally at both the level of selection and the level of learning, and hence it is easier for more laggard firms and industries to enter the green market once they identify interesting profit opportunities.

The paper has suggested that the greening of the economic process should be seen as one of the most innovative changes in recent economic evolution. We may interpret the green economic evolution as a specific historic era reflecting important changes in competitive conditions characterizing the modern knowledge economy. Increasingly other factors than costs matter for competitiveness. Selection properties become still more complex. In the knowledge economy users want to know more about the products and the companies that produces them than before. And that knowledge is more readily available and institutionalized. Modern economies have better developed means for dealing with the negative externalities of production, which have come to form an integrated part of the economic progress. The green economic evolution represents, overall, perhaps one of the most interesting cases of how selection properties are undergoing change over time, a strangely neglected theme in evolutionary economics.

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